Cosmic Acceleration

Top-level questions of the field:

1. Is cosmic acceleration caused by a new energy component or by the breakdown of General Relativity (GR) on cosmological scales?
2. If the cause is a new energy component, is its energy density constant in space and time, or has it evolved over the history of the universe?

WFIRST-AFTA addresses these questions using multiple methods to measure the history of cosmic expansion and structure growth, tightly constraining the properties of dark energy, the consistency of GR, and the curvature of space.

Supernova Survey: Distance measurements, $z = 0 - 1.7$.

Weak Lensing Survey: Growth of structure from cosmic shear, galaxy-galaxy lensing, abundance of massive clusters.

Galaxy Redshift Survey: Distance and expansion rate from baryon acoustic oscillations, growth of structure from redshift-space distortions.

Emphasis on cross-checks and control of systematics at every level.

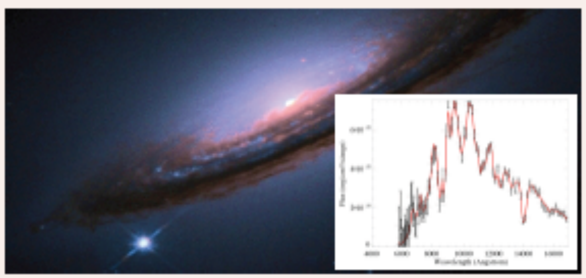
WFIRST-AFTA Dark Energy Roadmap

Supernova Survey

wide, medium, & deep imaging
+
IFU spectroscopy

2700 type Ia supernovae
$z = 0.1$–1.7

standard candle distances
$z < 1$ to 0.20% and $z > 1$ to 0.34%



High Latitude Survey

spectroscopic: galaxy redshifts

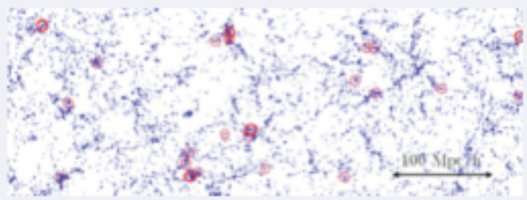
20 million Hα galaxies, $z = 1$–2
2 million [OIII] galaxies, $z = 2$–3

imaging: weak lensing shapes

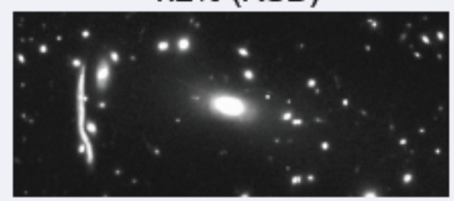
500 million lensed galaxies
40,000 massive clusters

standard ruler

distances	expansion rate
$z = 1$–2 to 0.4%	$z = 1$–2 to 0.72%
$z = 2$–3 to 1.3%	$z = 2$–3 to 1.8%

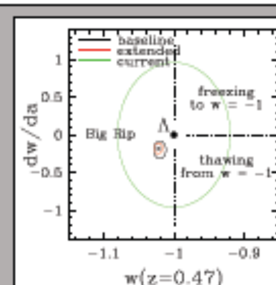


dark matter clustering
$z < 1$ to 0.16% (WL); 0.14% (CL)
$z > 1$ to 0.54% (WL); 0.28% (CL)
1.2% (RSD)



history of dark energy
+
deviations from GR

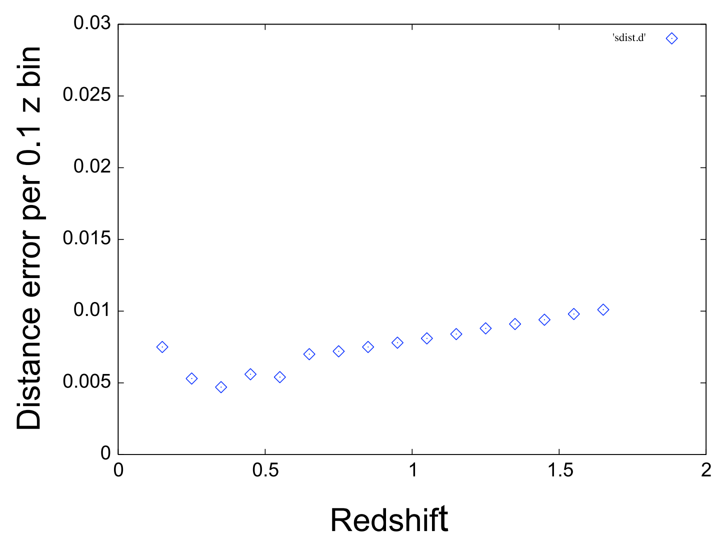
$w(z)$, $\Delta G(z)$, Φ_{REL}/Φ_{NREL}



The Supernova Survey

- Three tiered survey for low, medium, and high redshift Type 1a supernovae out to redshift of 1.7
- Use the Wide Field Instrument for supernova discovery with a 5 day cadence, the Integral Field Spectrometer (IFU) for lightcurves from spectrophotometry, no need for K corrections
- 2700 supernovae, distance errors 0.5 % to 1.0 % per 0.1 redshift bin including best estimate of systematic errors

- Low infrared background in space allows unique high redshift survey not possible from the ground
- High S/N spectra with the IFU allow reduced systematic errors to match high precision achievable with 2.4m



Weak Lensing with WFIRST

- Powerful probe of matter distribution in the Universe
  - Shapes for >400 million galaxies (50/arcmin^2 over 2400 deg^2).
  - Cosmic shear 0.??%[TBD] precision on amplitude of matter clustering from cosmic shear; also provides cluster-galaxy and galaxy-galaxy lensing.
  - High number density enables high-resolution mass maps
- Systematic error control
  - Shapes measured in 3 filters, with total of 6 passes over the sky: rich opportunity for null tests, auto- and cross-correlations, and internal calibration
    - Past surveys, in both WL and angular galaxy clustering, have shown correlations with scan direction or position in instrument field – key diagnostics of systematic errors.
  - Small and stable PSF with 2.4 m space telescope reduces systematic errors in the PSF model and their impact on galaxy ellipticity measurement
  - Dither pattern recovers full sampling, even rejecting cosmic rays at GEO rate

WFIRST Galaxy Redshift Survey

- Wide and Deep Galaxy Redshift Survey:
  - ~20 million Hα galaxies ($1<z<2$)
  - ~2 million [OIII] emission line galaxies ($2<z<3$)
  - Baseline survey area 2,400 $(\text{deg})^2$
- High Precision Measurement of Cosmic Expansion History and Growth History:
  - Model-independent measurement of cosmic expansion rate $H(z)$ & cosmic structure growth rate $f_g(z)\sigma_8(z)$ at a few % level with $dz=0.1$
  - Cumulative precision of $H(z)$ and $f_g(z)\sigma_8(z)$ at sub percent levels
- High Galaxy Number Density Allows Tight Control of Systematic Effects:
  - Good sampling of cosmic large scale structure
  - Enables subdividing data into subsets for crosschecks
  - Enables higher order statistics
  - More robust to Hα luminosity function uncertainties

BACKUP SLIDES

WFIRST-AFTA Dark Energy in Context

Current cosmological data consistent with flat ΛCDM, but several 2σ tensions.

BICEP2 illustrates potential for dramatic surprises from increased precision, importance of independent cross-checks.

WFIRST-AFTA complements other powerful dark energy experiments, such as Euclid, LSST, DESI:

- Unique space-based supernova cosmology survey.
- Deep, high angular resolution near-IR imaging.
- Weak lensing with space-based PSF, multiple passes and filters for systematics control.
- Deep galaxy redshift survey, densely sampling large scale structure at z = 1-2, plus [OIII] tracers at z = 2-3.

WL: A completely different regime

- WL with AFTA survey would reach >50 galaxies per square arcminute
  - vs ~30 w/Euclid, and even fewer from the ground
- With a deeper survey AFTA could reach HUDF depths of **>300** galaxies per square arcminute in selected regions

This is a fundamentally different WL regime that is not possible from the ground or with a 1.3 meter class telescope due to PSF size.

- Does not necessarily help with DE FoM (wide>deeper for FoM)
- Much better calibration data
- *Much* better for understanding dark matter